Viewing Inside a LArTPC with a Raspberry Pi Camera

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Abstract

Liquid Argon (LAr) Time Projection Chambers (TPCs) are the technology of choice for the future neutrino program at Fermilab. These detectors consist of thousands of stainless steel or beryllium-copper sensing wires, which detect ionization electrons produced in neutrino collisions inside the detector. These wires are a couple hundred microns thick and range from tens of centimeters to several meters in length. The construction of these detectors often takes place in an assembly hall, which is different from where the experiment will operate, and so these detectors must be moved. Furthermore, access to the TPC and its wires inside the LAr-containing cryostat is limited. This project investigates a cost-efficient means of viewing the integrity of the wires after moving the detector without penetrating the cryostat. A Raspberry Pi (RPi) single-board computer connected to a low-cost camera could view wires inside the detector for less than $60. Mounting many of these throughout the detector will allow one to check the integrity of all the wires for a low cost. The low cost is important because the RPi and camera will likely not work once the detector is filled with LAr. The RPi and camera will be tested in a dedicated LAr materials test stand at Fermilab to ensure contamination will not be introduced that will reduce the lifetime of ionization electrons as they drift towards the sense wires. Finally, a RPi and camera may can be used to monitor detector access, condensation on signal feed-throughs, or the status of electronic LED indicators.

Motivation

LArTPCs provide great resolution of tracks and electromagnetic showers.

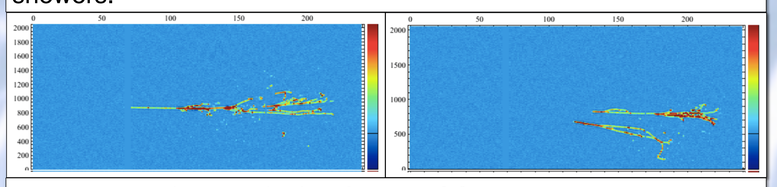


Figure 1. Example event displays for SBND [1].

Most recent LArTPC is the MicroBooNE detector.
- Largest LArTPC in America (80-ton active mass)
- 8,256 wires (3 mm pitch)

Construction often takes place in an assembly hall; after which, the detectors must be moved.

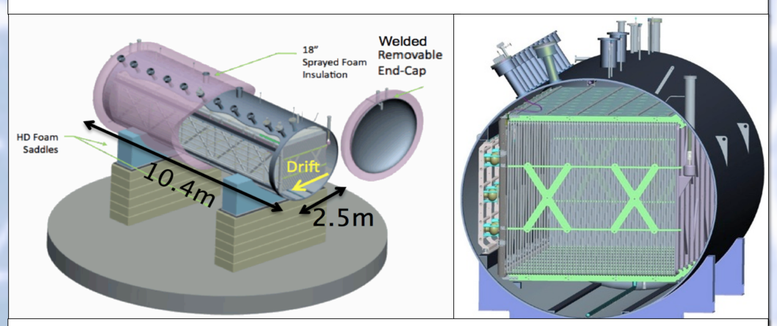


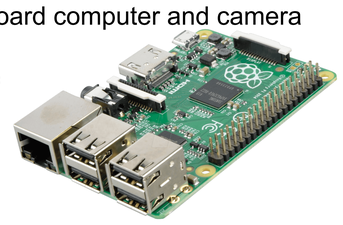
Figure 2. The MicroBooNE detector [2].

After construction, the detectors must be moved.

Figure 3. The MicroBooNE detector in transit to LArTF.

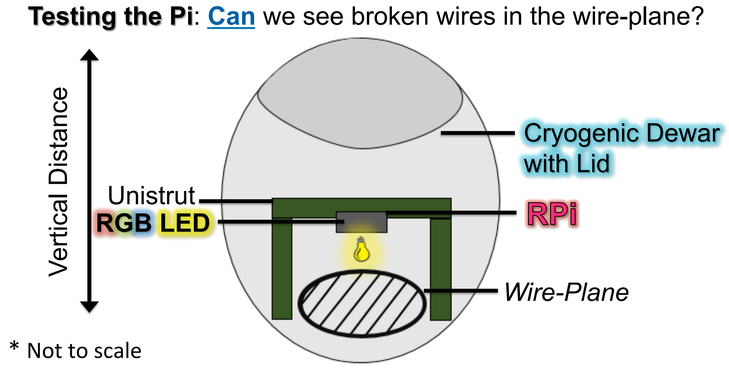
Equipment

- RPi: Credit card-sized single-board computer and camera
- Values at less than $60
- Mouse and keyboard or laptop
- Linux Operating System
- We used Python as the main operating system.
- Ethernet Cable



Experimental Setup

Testing the Pi: Can we see broken wires in the wire-plane?



* Not to scale

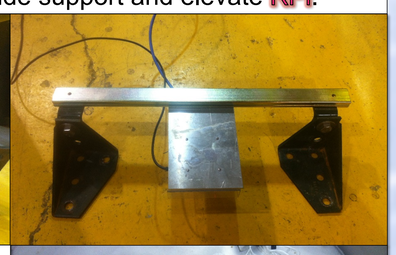
Figure 4. Schematic of RPi testing in cryogenic dewar.

Construction

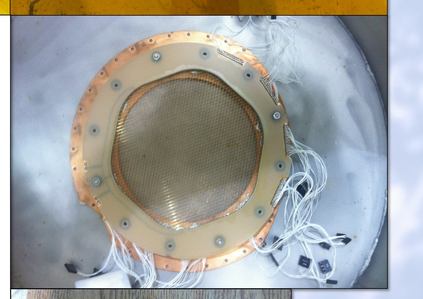
1. Place Kapton tape (electronically insulating) on surface of aluminum thin slab.
2. Screw on RPi.
3. Attach Lexan plastic sheet.

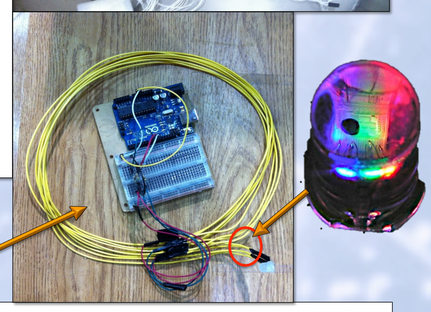
- Lexan sheet covers the top portion of the RPi for protection.
- The bottom is not covered to allow access to an Ethernet port.

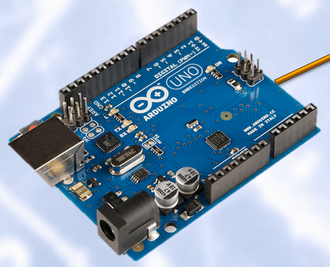
4. RPi was then mounted to unistrut.
5. Legs were assembled to provide support and elevate RPi.



6. Two *wire-planes* were placed in the cryogenic dewar.
7. A cryogenic dewar was used to simulate the inside of LArTPCs.
8. A lid was used to recreate the dark conditions inside a detector.
9. Soldered RGB LED to two long wires & then taped to RPi.
10. Used Arduino to power RGB LED on and off.







- An Arduino is a credit card-sized microcontroller that is similar to an RPi.
- Used Arduino and breadboard to program RGB LED.

Web Interface

- Programmed a web interface for the Pi camera that can be opened on the Fermilab computing network.
- Can be viewed in read time and accessed remotely.
- Record still image and video.
- Still image and video can be saved on the SD-card.
- Download and delete saved video and picture.
- Control Pi Cam features such as brightness, contrast, etc.

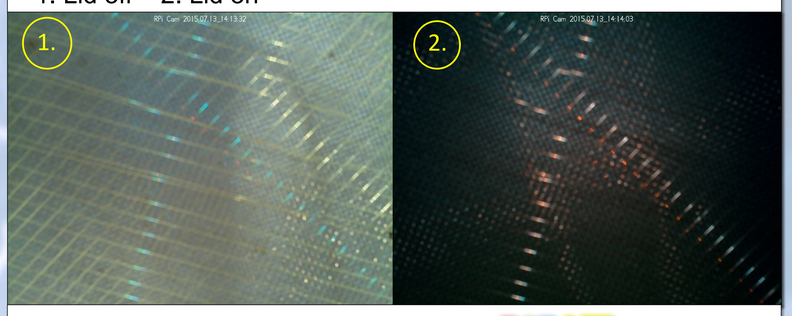
Results

1.56 in. from wire-plane with no RGB LED and the Lid on

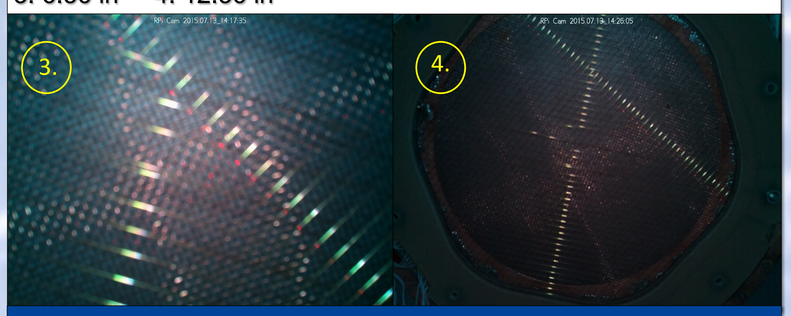
Why use an RGB LED?

Because otherwise it doesn't get much better than this!!!

1.56 in. from wire-plane with RGB LED
1. Lid off 2. Lid on



At varying distances from wire-plane with RGB LED and lid on
3. 6.56 in 4. 12.56 in



Other Applications

RPis and cameras may also be used to monitor:
- Detector access
- Condensation on signal feed-throughs
- Status of electronics and LED indicators.
- Control rooms

Summary

Great resolution at a variety of distances!!!
- Can still see broken wires.
- Can see wires on both wire-planes.
- Illumination is sufficient with an RGB LED.
- Further testing will be conducted at Luke Materials Test Stand at Fermilab to see how long the RPi survives in LAr.

Acknowledgments

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References

[1] M. Antonello, et al., "A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam," arXiv:1503.01520v1 (2015).
[2] M. Toups, MSU HEP Seminar.

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